Date: 5th March 2021

EIC Detector R&D Progress Report

Project ID: eRD27
Project Name: Developing a high resolution ZDC for EIC
Period Reported: from 1 October 2020 to 5th March 2021
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Abstract

The Electron Ion Collider offers the opportunity to make un-paralleled multidimensional measurements of the spin structure of the proton and nuclei, as well as a study of the onset of partonic saturation at small Bjorken-x. An important requirement of the physics program is the tagging of spectator neutrons and the identification of forward photons. We propose to design and build a Zero Degree Calorimeter, or ZDC, to measure photons and neutrons with excellent energy & position resolution.

Past

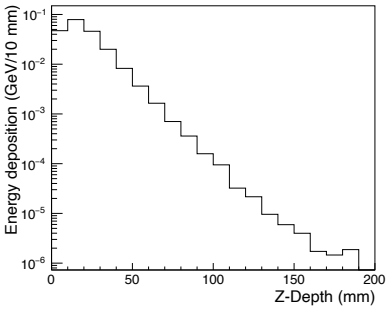
What was planned for this period?

The original proposal called for

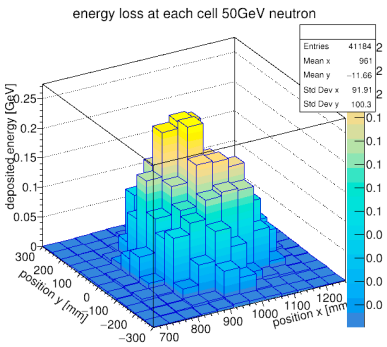
1) Integration of Physics tools at KU
2) Test against physics requirements
3) Study of energy and Pt resolution

However upon advise of the program committee we decided to focus in particular on low energy photon reconstruction.

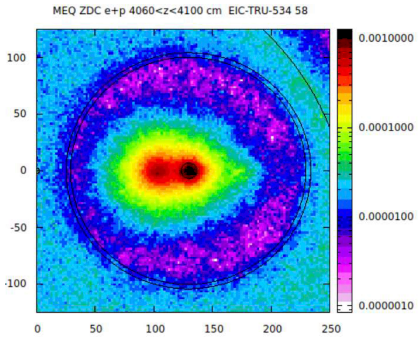
What was achieved?



Dr Quan Wang adapted the G4E framework to the ZDC case. The requirement for reconstructing 400 MeV photons was considered to be beyond the capabilities of the electromagnetic section of the CMS Cherenkov Fiber/Tungsten ZDC. Therefore we focussed on crystals. Because of our FOCAL experience we started with $PbWO_4$. In particular we sought to understand the minimum thickness of an electromagnetic section needed for 400 MeV photons. The plot above shows energy deposition versus depth of 400 MeV photons in $PbWO_4$. It is clear that a 10cm section should be sufficient to tag these photons.



Since $PbWO_4$ is not particularly radiation hard we have begun a study of the dose that is to be expected for the ZDC. Graduate student Yuya Ohsumi of Kobe has done this as a function of beam energy and neutron transverse momentum. The picture to the right shows the dose map for a 100 GeV neutron near shower maximum. If it is assumed that all neutrons have transverse momentum, p_T = 100 MeV/c then the maximum dose is $1.5\ 10^{-10}$ Gy/event. This falls rapidly as the p_T of the neutrons increases. The next steps is to use realistic generators such as BeAGLE or FLUKA.



As part of our collaboration with eRD21 Dr Vitali Baturin of ODU has shared his calculations the neutron fluence from ep collisions near the ZDC. The figure to the right show the neutron fluence in n/cm^2 for 130 GeV ep collisions, (the proton beam is coming out of the paper). Vitaliy is investigating the origin of the background to see if timing cuts could reduce it.

What was not achieved, why not, and what will be done to correct?

We have not yet implemented detailed optical tracking within the crystals. This was delayed be the need to buy a more powerful computer for these studies. We believe that we now have sufficient information from studies by the FOCAL group to implement this efficiently.

How did the COVID-19 pandemic and related closing of labs and facilities affect progress of your project?
Test beam was pushed back and hosting collaborators at Kansas, or Japan, was not feasible.

How much of your FY20 funding could not be spent due to pandemic related closing of facilities?
Because of Covid the earliest we can have test beam is October 2021. It is still very difficult to invite Japanese visitors to Kansas. Therefore we will not be requesting travel funds in FY2021.

Do you have running costs that are needed even if R&D efforts have paused?
No

Future

What is planned for the next funding cycle and beyond? How, if at all, is this planning different from the original plan?

We will finish out standalone studies of the ZDC energy resolution for our current configuration. However we will delay studies of neutron position resolution in order to focus on developments with the EIC beam pipe and for photons the use of a pre-shower detector within B0. We are also seeking to expand our group by starting a forward detector consortium. In October we hope to take test beam data with a position dependent ZDC designed for the High Luminosity LHC. This will provide useful data on the what is feasible for Cerenkov based calorimeters.

What are critical issues?

Recently Alex Jentsch has alerted us to a concern about the beam pipe in the forward region. Because of shallow angles with respect to the neutron cone some neutrons may see as much as 10 cm of beam pipe. This is an important issue to address and perhaps iterate with the machine group. We hope to get step files for the current beam pipe in the next two weeks and will then incorporate them in to

G4E. Accurate simulations of the beam pipe will be essential before we can approach the beam group about possible modifications in either geometry or materials.

For photon reconstruction the use of a pre-shower within B0 could provide complimentary information to the ZDC. We plan to make a preliminary investigation of this in the next months.

Additional information:
In order to produce a TDR we estimate that we would need 1.5 -2.0 FTE postdocs for the period fall 2021 to fall 2023. During this period at least 2 test beam campaigns would be required. Support for two students would be very helpful.

Manpower

Include a list of the existing manpower and what approximate fraction each has spent on the project. If students and/or postdocs were funded through the R&D, please state where they were located, what fraction of their time they spend on EIC R&D, and who supervised their work.

Since starting on the project in late November Quan Wang of Kansas has spent about 20% of his time on ZDC studies, supervised by Michael Murray. Yuya Ohsumi of Kobe has spent 50% of his time supervised by Y. Yamazaki. So far Vitali Baturin has spent 0% of his time dedicated to eRD27 but this will increase to 10% for the remainder of this funding period. He will be supervised by Charles Hyde.

External Funding

The Kansas group recently obtained ~$73K over two years for from DOE-HEP R&D funds, in collaboration with Northern Illinois University, for development of fast timing for forward calorimeters. This work is just starting and is not reflected in this report. The Kansas group is also collaborating with UIUC on building identical ZDCs for ATLAS and CMS at the HL-LHC.

Publications

Performance of the CMS Zero Degree Calorimeters in pPb collisions at the LHC
O. Surányi, et al.Feb 12, 2021, e-Print:2102.06640 [hep-ex], accepted by JINST.